

# Nano-EHS and the United States Measurement System

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USMS Nano-EHS Webinar

May 6, 2009



# Objectives

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- ✿ What is the United States Measurement System (USMS)?
- ✿ What does it mean to Assess the USMS?
- ✿ What is the Measurement Knowledge Hub?
- ✿ Measurement Needs and Solutions in Nano-EHS sector
- ✿ Discussion of Opportunities
- ✿ The Path Forward

# Poll: Are you Aware of the existence of the 2007 USMS Assessment Report?

Yes

No



# United States Measurement System

## What?

- The set of measurement solution providers and users, and the relationships among them

## Why?

- Promote U.S. innovation and industrial competitiveness via
  - Increased effectiveness and efficiency in developing and deploying measurement solutions

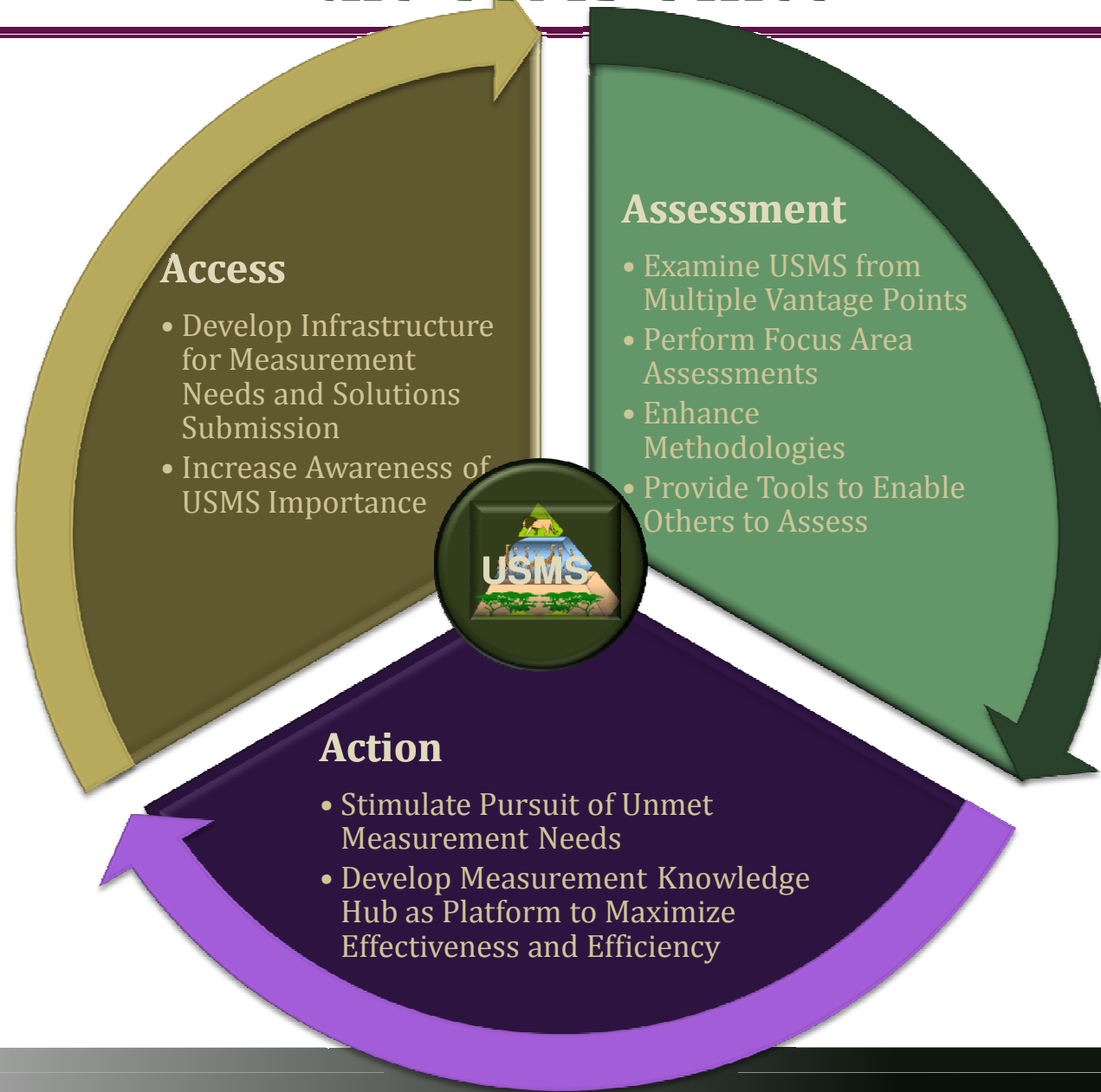
## How?

- By identifying and fostering efforts to address unmet measurement needs



- Documents 723 measurement barriers to innovation
- Covers 11 industry sectors
- Over 1000 contributors from industry, academia, and other government agencies

# NIST's Other Role in the USMS: the USMS Office



## Action: What's in it for me?

- ✧ Inform strategic decision making
- ✧ Accelerate development of critical measurement solutions
  - ✧ Identify and authenticate existing measurement needs & solutions
- ✧ Customer Input (e.g. Needs, Priorities)
- ✧ Identify opportunities / Educate / Communicate

# Basis for Assessment: Authenticated Measurement Needs (MN)

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- ✿ MN Template
- ✿ Tags / Indicators
  - ✿ MN Characteristics that may be used to compare MNs
- ✿ Authentication
  - ✿ Evidence of a significant number of interested users for any measurement solution that is developed



## Case Study Measurement Need: *Toxicology of Nanoparticles in Biological Systems*

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***Technological Innovation at Stake:*** Product innovations that use nanoparticles are rapidly expanding in many sectors of the world economy with their incorporation into a wide range of products including cosmetics, pharmaceuticals, polymer composites, clothing, and microelectronics. Despite the potential gains from nanoparticle-based products, there is concern by many communities about their toxicity. The unique and diverse physico-chemical properties of nanoscale materials suggest that toxicological properties may differ from materials of same or similar composition but larger size. For example, nanoparticles may readily migrate through normal barrier tissues such as skin, enter into the blood stream and from there penetrate internal barrier tissues entering into organs like the brain.

***Economic Significance of Innovation:*** Between 1997 and 2003, worldwide government investment in nanotechnology rose from \$432 million a year to just under \$3 billion a year. Discoveries made in nanoscience and nanotechnology are expected to be a major driver of the world economy in the next decade. However, despite the economic impact nanotechnology can yield through its novel properties, the lack of sound toxicology of nanoscale structures in humans and animals has the potential to derail the acceptance of nano-structured materials in the marketplace.



## Case Study Measurement Need: *Toxicology of Nanoparticles in Biological Systems*

***Technical Barrier to the Innovation:*** Effective and accepted methods to assess nanoparticle toxicity do not exist. Evidence demonstrating the migration of nanoparticles through barrier tissues in mammals has only recently been shown. New measurement methods are needed for both clinical effects of nano-structure incorporation in tissues and for characterization of nano-structures through out their life, i.e., before incorporation in tissues as well as following incorporation. It is expected that once incorporated in living tissues, nano-structures will change. Methods having the capability to determine such changes in-situ will greatly aid the understanding the evolution of nanostructures in the body.

***Measurement-Problem Part of Technical Barrier:*** Development of usable dose metrics for nanoparticle toxicity is not possible without accurate methods to characterize nanoparticle properties such as composition, dimensional metrology, surface area, shape and structure. In addition the development of dose metrics will also depend on the ultimate fate of nanoparticles in biological tissues. Measurement methods sensitive to both the physical and chemical structure and properties of nano-structures are needed as a basis for assessing toxicological impact of nanoparticle materials in tissues.

## Case Study Measurement Need: *Toxicology of Nanoparticles in Biological Systems*

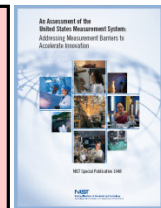
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- ✿ ***Stage of Innovation Where Barrier Appears:*** R&D
- ✿ ***Potential Solutions to Measurement Problem:*** None yet identified – need a more thorough assessment of the area, possibly nanoparticle- and mammal-specific

# Using Measurement Needs to Assess the State of the USMS

- ✱ Gather Authenticated Measurement Needs
- ✱ Analyze and Aggregate
  - ✱ Sets of Measurement Needs
  - ✱ Roadmaps / Key Documents
- ✱ Apply Expertise
  - ✱ Derive Inferences / Findings
  - ✱ Authenticate Inferences / Findings

Phase I Assessment: Over 700 measurement needs were identified in 11 sector/technology areas, with input from 322 individual measurement needs and 162 technology roadmaps



# Assessment: Current Focus Areas

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- ✿ **Nanotechnology Environmental, Health & Safety**
- ✿ **Alternative Energy**
  - ✿ Hydrogen / Fuel Cells
  - ✿ Biomass
  - ✿ Infrastructure / Smart Grid
  - ✿ Solar / Photovoltaic
  - ✿ Nuclear
- ✿ **Core Metrology**
- ✿ **Sensors for Civil Infrastructure**
- ✿ **Carbon Mitigation Strategies**
- ✿ **Biosciences**

# Measurement Knowledge Hub: Current Operational Features

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- ✿ Measurement Needs
  - ✿ Search
  - ✿ Entry
- ✿ Blog: *A Measure Above*
- ✿ Forums
- ✿ Webinars

<http://usms.nist.gov>

<http://usms/nist.gov>

(Clare will control the website navigation at this point so that all can see what I am doing)



# What's Next?

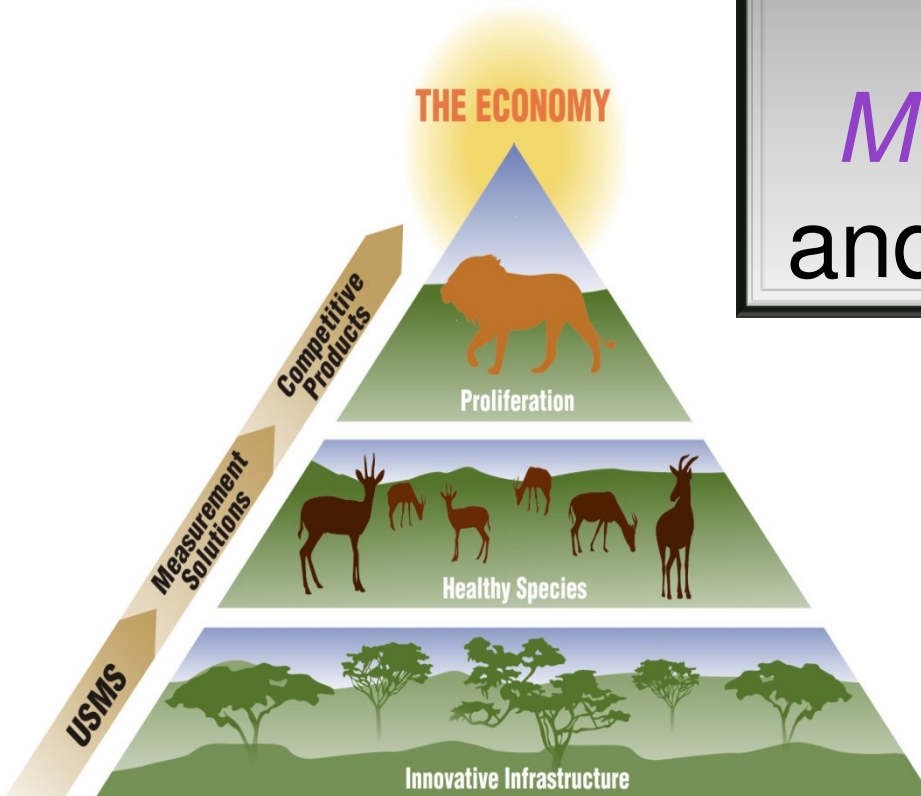
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- ✿ Provide New Functionalities for the Measurement Knowledge Hub
- ✿ Release Assessment Report #2 (2009)
- ✿ Continue to Pursue Resources for Unmet Critical Measurement Needs
- ✿ Continue to Facilitate Action to Address Measurement Needs
- ✿ Continue to Promote USMS Access and Awareness



# The US Measurement System...

...where  
*Measurement Science*  
and *Innovation* converge

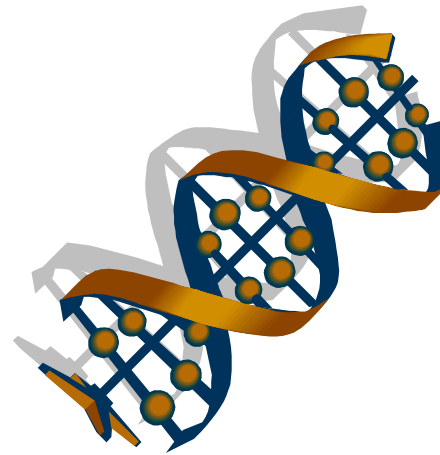


For more information:

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[Clare.allocca@nist.gov](mailto:Clare.allocca@nist.gov) /301-975-4359

# Preliminary Findings: Nano-EHS Measurement Needs



# Agenda

- Scope of Nano-EHS
- Objectives of Nano-EHS assessment
- Methodology
- Preliminary assessment of Nano-EHS Measurement Needs

# Terminology

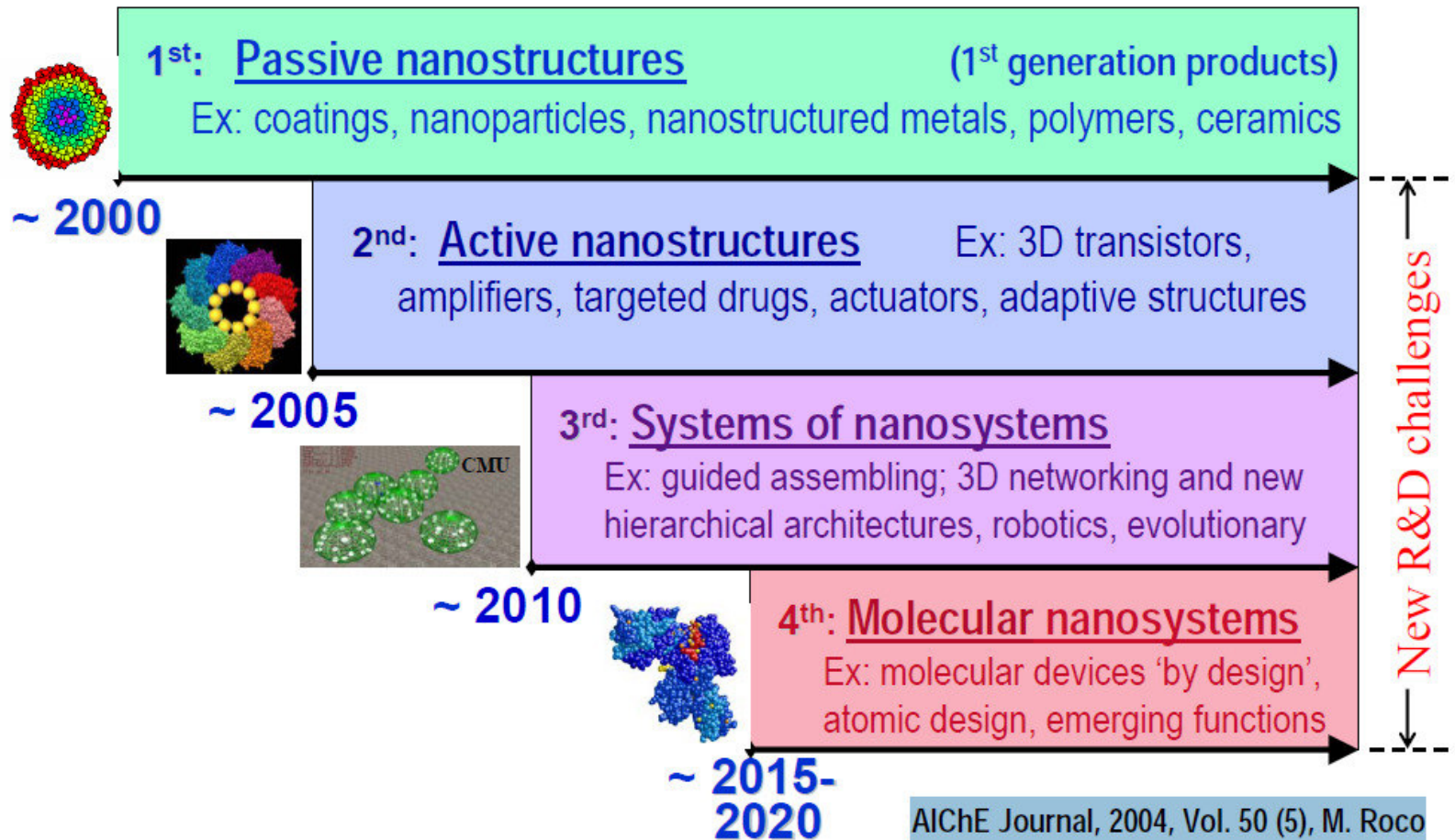
***Nanoscience*** involves research to discover new behaviors and properties of materials with dimensions at the nanoscale which ranges roughly from 1 to 100 nm. ***Nanotechnology*** is the way discoveries made at the nanoscale are put to work. Nanotechnology is more than throwing together a batch of nanoscale materials-it requires the ability to manipulate and control those materials in a useful way.

**Environment** - air, soil, water, and other media that make up the world in which we live

**Health** - general condition of the body, including both human and animal

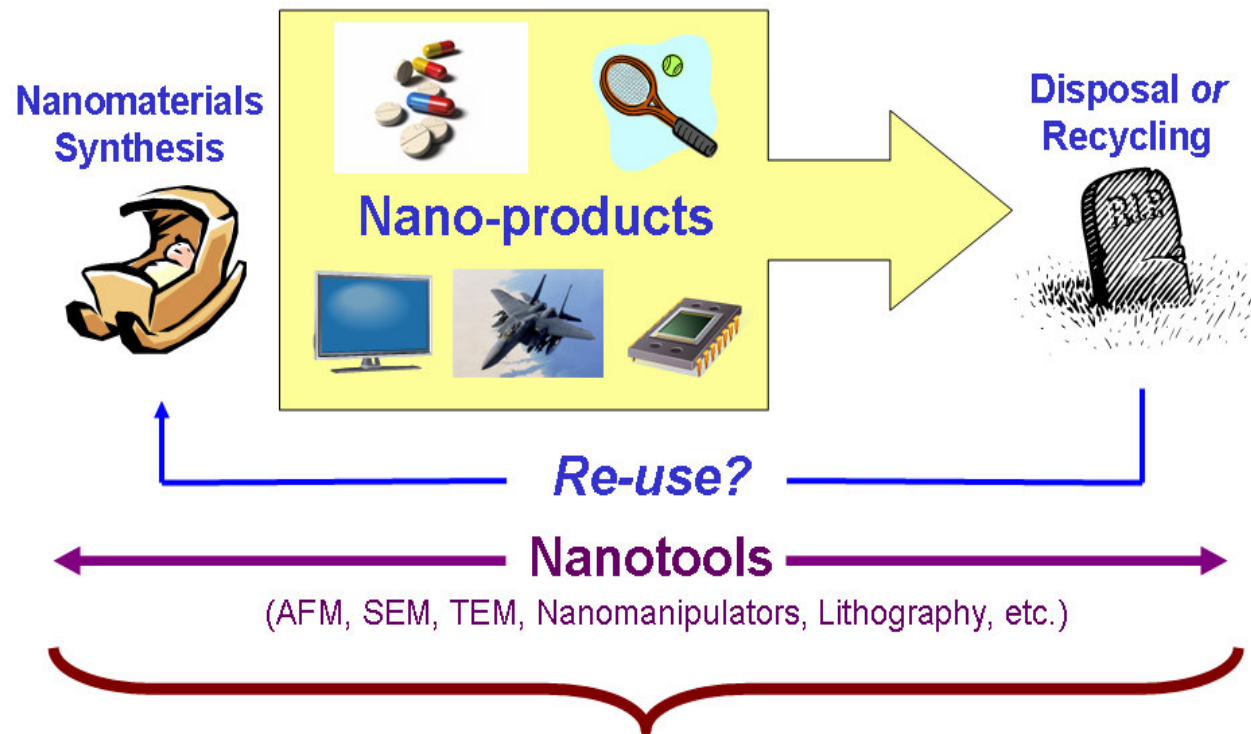
**Safety** - protection from harm to the worker in the occupational environment and the general populace in living places

# Motivation



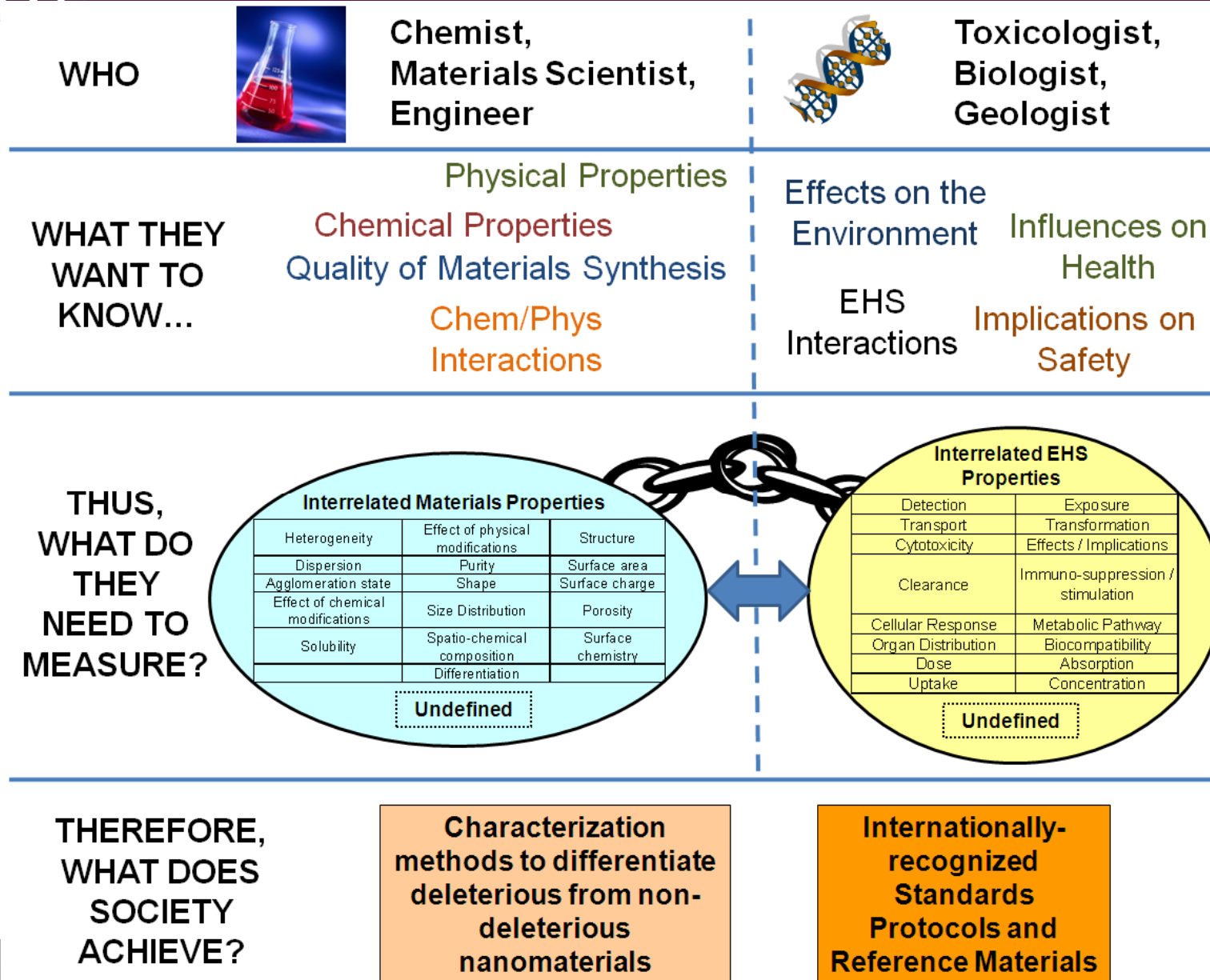
# Nanomaterials Life Cycle

## *Cradle-to-Grave Perspective of Nano-EHS*





# Methodology: Subcategories





# Objectives

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## **Are EHS measurement needs limiting factors in bringing nanotechnology to market?**

- Investigate Nano-EHS challenges
- Create list of preliminary MNs to start dialog
- Analyze MNs – overall trends

# Methodology: Overview

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- Identify and review multiple publications
- Create list of Nano-EHS subcategories
- Input preliminary MNs in database
  - MN descriptions
  - Tag MNs
- Analyze MN dataset

# Methodology: Literature Review

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- Readily available publications were reviewed - these included:
  - Roadmaps
  - Industry reports
  - Conference presentations
- Not an exhaustive review of every Nano-EHS report published
- List of reviewed publications will be available on the USMS website (<http://usms.nist.gov>)
- Please suggest additional resources via USMS website forums
- Experts in nano-EHS were also consulted for submission of individual measurement needs

# Methodology: Database

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- Input of MNs to Excel database included:
  - 157 MNs (32 measurement needs contributed by expert individuals and 125 roadmap measurement needs identified from earlier authenticated roadmaps, workshops and/or white paper publications)
  - Descriptions
  - Tags (standardized keywords)
- Database enables us to:
  - House MNs in a central location
  - Quickly analyze distribution of MNs within the Nano-EHS sector and across various economic sectors
  - Easily produce reports related to MNs

# Methodology: Database

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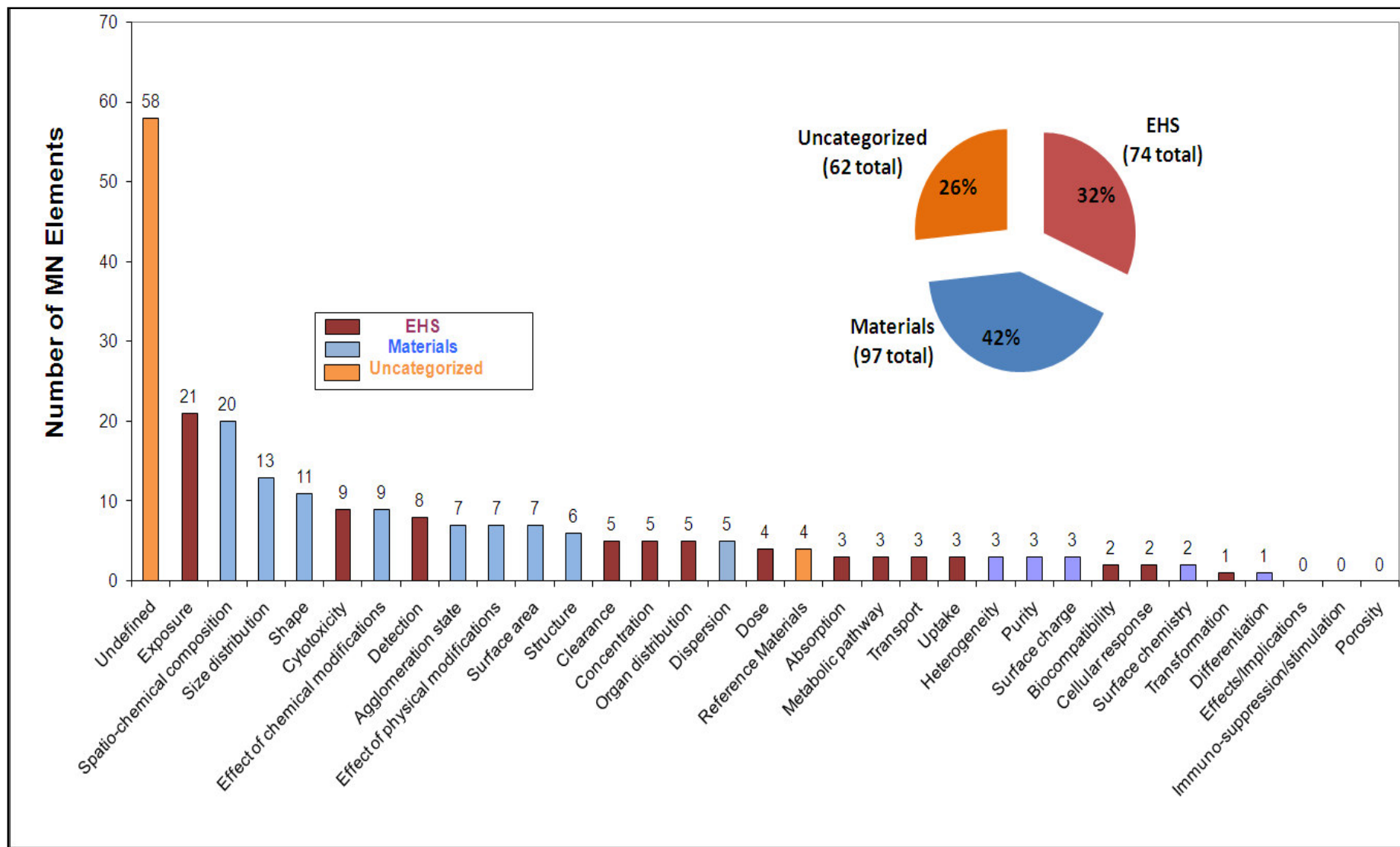
- Tags assigned to each MN allow grouping and analysis of Nano-EHS sector.
- Tag categories include:
  - Subcategory
  - Stage of technology
  - Measurand (property to be measured)
  - Measurement Barrier
  - Measurement Solution
  - Nano-EHS specific Tags
  - Solution Providers

# Preliminary MNs: Overview

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- Subcategories
- Recurring themes in preliminary MNs
- Analysis of preliminary MN assessment
- Your input

# Interrelated Measurand Properties

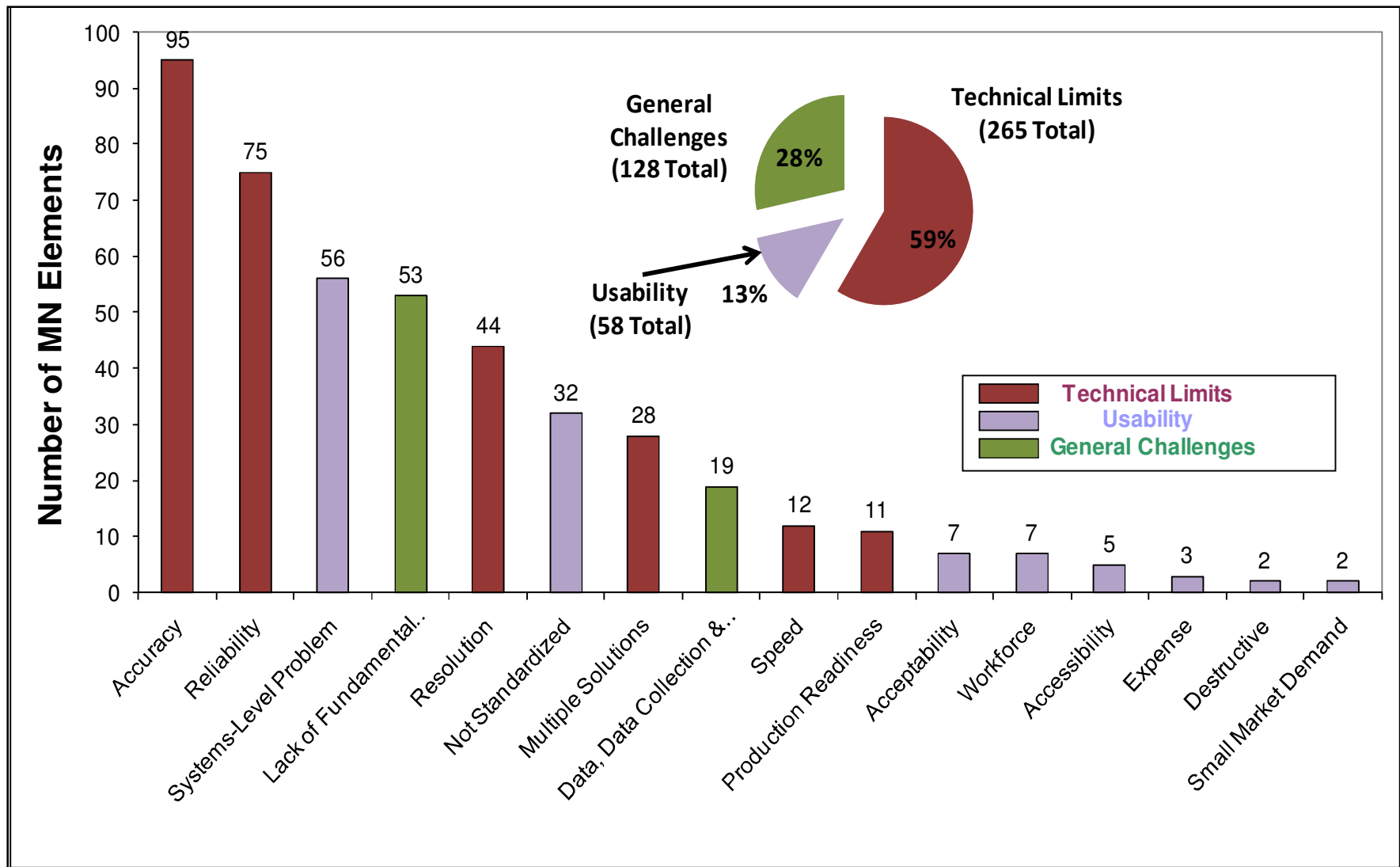




# Interrelated Measurand Properties

- A theme among the Roadmaps is a need for greater specificity in their MN descriptions.
- The basic research needed to address Nano-EHS MNs is not yet done.
- The largest category is Undefined, which in and of itself is quite telling - we need a better understanding of the basic process and scaling.
- Materials Measurands appear to be the strongest message as of this writing from among the Nano-EHS community, although EHS Measurands are close behind
- Aside from the Undefined Measurand, the top five Measurands are, in descending order: Exposure, Spatio-chemical composition, Size distribution, Shape, and Cytotoxicity. This is important to recognize from the perspective of allocating funding and strategic planning in general.

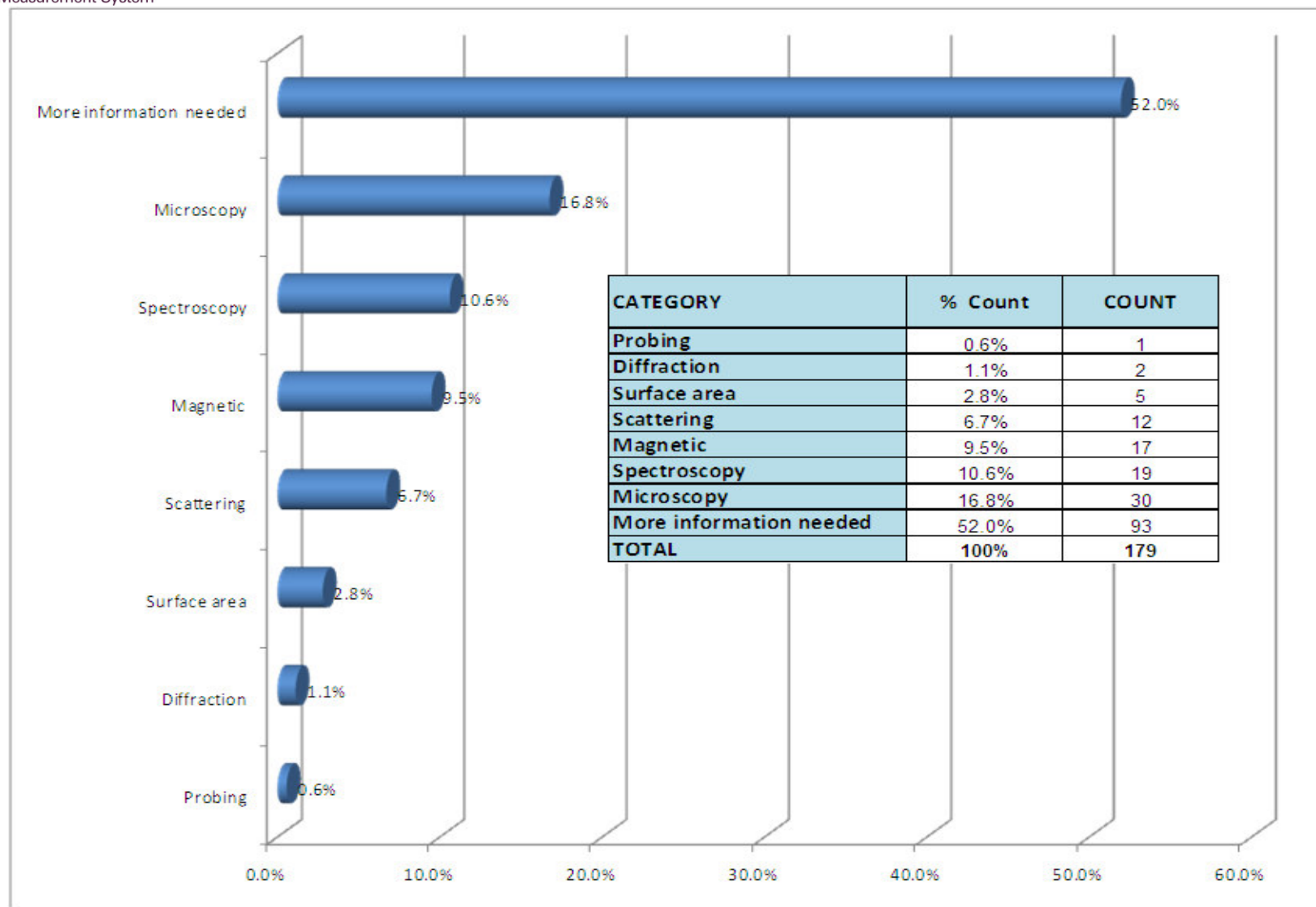
# Measurement Barriers



# Characterization Equipment

Major Characterization Equipment Categories								
<b>Conductivity (electrical, thermal)</b>	Conductivity Meter							
<b>Diffraction</b>	XRD (X-ray diffraction)	Neutron Diffraction	Electron Diffraction					
<b>Magnetic</b>	Magnetometer	MRI (magnetic resonance imaging)	NMR (nuclear magnetic resonance)					
<b>Microscopy</b>	SPM (scanning probe microscopy)	STM (scanning tunneling microscopy)	NSOM (scanning near field optical microscopy)	TEM (transmission electron microscopy)	STEM (scanning transmission electron microscopy)	SEM (scanning electron microscopy)	CLSM (confocal laser scanning microscopy)	
<b>Probing</b>	Nanoprobe (multiprobe electrical measurements and sample manipulation)	Nano-indentor						
<b>Scattering</b>	SANS (small angle neutron scattering)	SAXS (small angle X-ray scattering)						
<b>Spectroscopy</b>	XAS (X-ray absorption spectroscopy), which includes XANES (X-ray absorption near edge structure) and EXAFS (extended X-ray absorption fine structure)	XPS (X-ray photoelectron spectroscopy) also known as ESCA (electron spectroscopy for chemical analysis)	AES (Auger electron spectroscopy)	SIMS (secondary ion mass spectrometry)	FT-IR (Fourier transform infrared spectroscopy)	Raman Spectroscopy	EDS & WDS (energy dispersive spectroscopy); (wavelength dispersive spectroscopy)	EELS (electron energy loss spectroscopy)
<b>Surface area</b>	BET							

# Frequency of Possible Measurement Solutions for Nano-EHS Measurement Needs



# Summary of Findings

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- ✿ Preliminary assessment indicates that Nano-EHS is still early in its R&D time continuum
- ✿ Measurement Needs information in the Roadmaps is often quite general.
- ✿ A significant number of MNs indicate a need for instrumentation that can handle complexity and scale beyond current limits.
- ✿ A convergence among multiple levels, organizations and disciplines is needed to address many of the Nano-EHS measurement needs; the infrastructure for this convergence may not exist currently.

# Summary of Findings

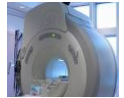
- The lack of clarity and consensus of terminology can be impediments to a common understanding across disciplines, *e.g.*, toxicologists and materials scientists.
- There exists a common thread among almost all the roadmaps and researchers in the types of MNs being requested; differences lie among the details, *e.g.*, how a specific nanomaterial is measured. The next level of measurement needs assessment may be in these details.

Poll: Do you agree with the overall  
analysis / findings?

Yes

Yes, with additions or reservations

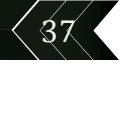
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Poll: With respect to the Nano-EHS  
Measurement Needs, how appropriate  
was the level of technical detail?

Appropriate  
Not Enough  
Too Much



# Preliminary MNs

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- **Your input is important!**
  - Ranking/prioritizing of preliminary Nano-EHS MNs
  - Joining USMS web community
  - Comment on forum posts
  - Author new MNs
  - Refine preliminary list of MNs

**VISIT <http://usms.nist.gov/>**

# Measurement Needs Survey Subcategories

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- ✿ Nanomaterial Properties
- ✿ Exposure
- ✿ Sensors and Instrumentation
- ✿ Biocompatibility

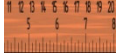
# Next Steps

- Collect comments on preliminary Nano-EHS MNs
- Grow the list of Nano-EHS MNs with help from the nanotechnology community
- Publish report discussing this sector-specific assessment

# Poll: Are you willing to co-author a Measurement Need?

Yes

No



# Nano-EHS Community: The Path Forward

- ✿ Grow list of MNs
- ✿ Assess USMS
- ✿ Authenticate MNs and Assessment Findings
- ✿ Develop Path to Critical Measurement Solutions
- ✿ Follow-on Forums, Webinars and/or Live Workshops

<http://usms.nist.gov>

# Poll: Would you be interested in a follow-on Webinar?

Yes

No



# Poll: Are you interested in participating in a Working Group on Nano-EHS Measurement Needs?

Yes

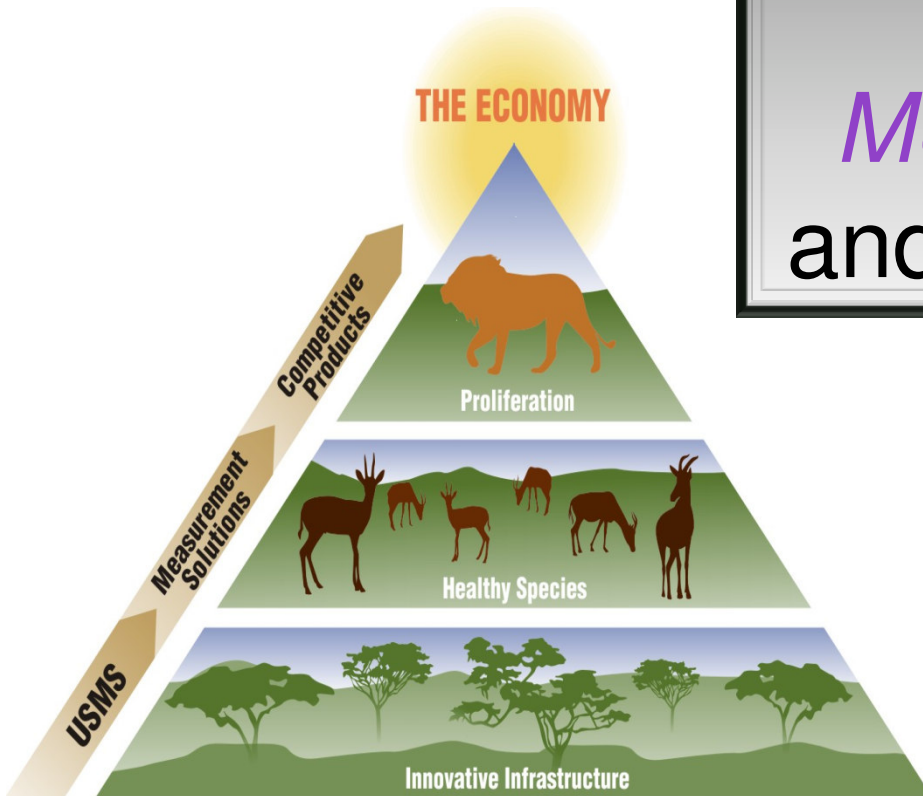
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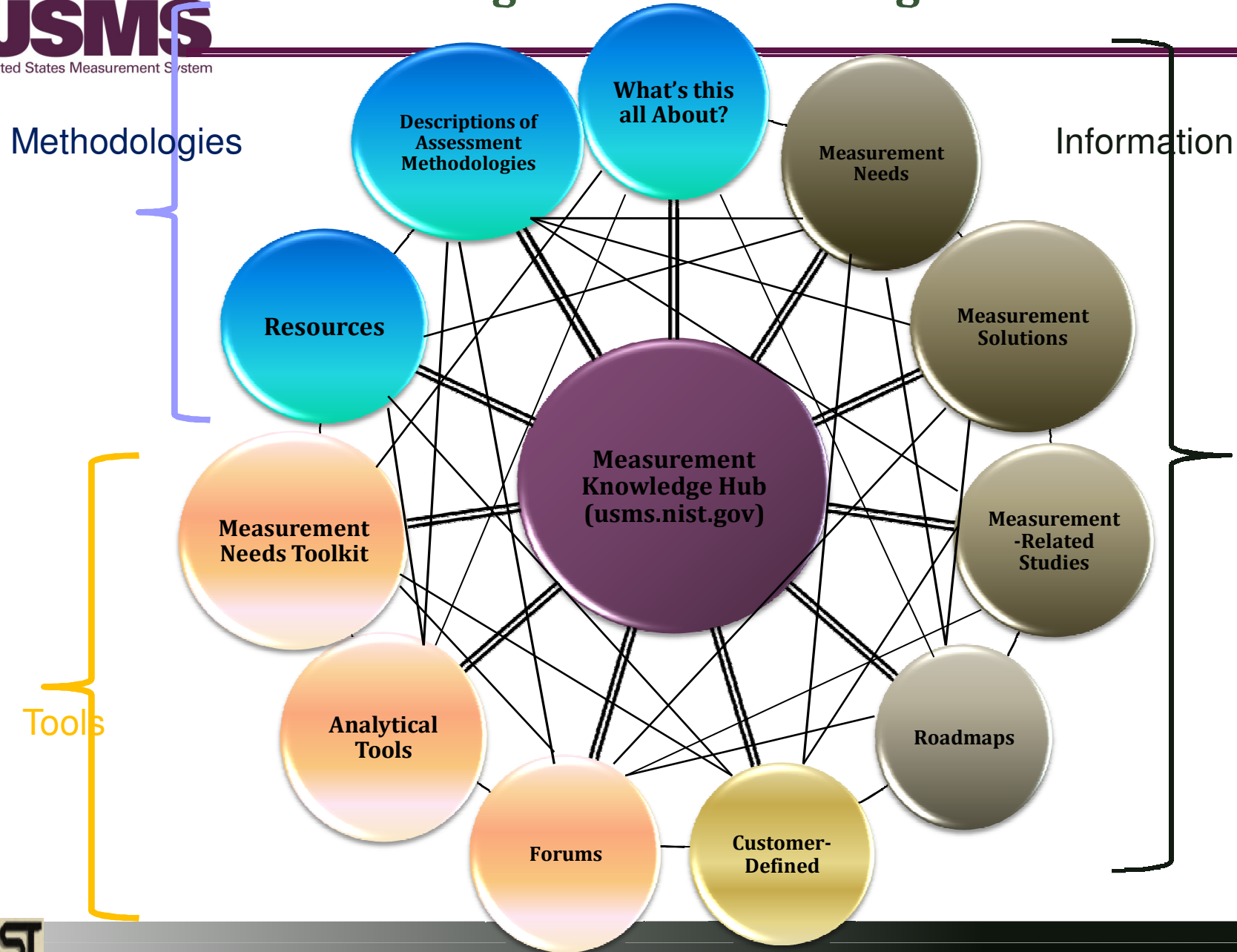


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# Measurement Knowledge Hub (MKH): A Web-based Meeting Place for all Things Measurement



# Measurement Knowledge Hub: Future Operational Features

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- ✿ Measurement Needs
  - ✿ Analysis
- ✿ Roadmaps Database
- ✿ Measurement Solutions
- ✿ Measurement Needs & Solutions Toolkit
- ✿ Assessment Reports